

# SCIENCE FOR CERAMIC PRODUCTION

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## PROPERTIES OF POROUS PERMEABLE CERAMIC BASED ON MONOFRACTIONAL CORUNDUM POWDERS AND NANODISPERSED BINDER

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It is concluded on the basis of calculations performed for different types of close packing of spherical particles that porous permeable ceramic materials with open porosity greater than  $42 \pm 3\%$  it is can be created, in practice, from monofractional corundum powder. It is shown that the formation method (semidry pressing and slip casting) and the habit of the crystals affect the open porosity of the ceramic. The chemical resistance of the porous ceramic materials obtained to nitric acid and sodium hydroxide is evaluated.

**Key words:** porous permeable ceramic, monofractional powders, corundum, nanodispersed binder, sols.

The problem of doubling the gross domestic product is closely linked with solving problems of ecology and the conservation of nonrenewable resources. One of the primary paths for solving such problems could be developing new ceramic materials, organizing the production of diverse articles from them, and wide industrial application of these articles as replacements for obsolete conventionally used materials. Porous permeable ceramic is one such promising material [1].

Articles made from such ceramic are finding increasing industrial applications including, among many other applications, removing water from hydrometallurgical pulps after flotation, blowing inert gas through metal melts to mix the gas, filtering ferrous and non-ferrous metal melts to remove impurities from them, removing dust and admixtures of harmful gases from hot exhaust stack gases, flotation, aeration, and ozonation of water systems in fine-bubble gas-distribution systems, pneumatic transport and mixing of pulverized materials and highly dispersed powders, removing radioactive impurities from hot stack gases, removing solid impurities from solutions of metal electrolytes, and removing solid impurities from water in water recycling systems [2].

The interest in articles made of porous permeable ceramic based on aluminum oxide is dictated by a special combination of properties which are inherent only to this material — high resistance to acid and alkali, high operating tempera-

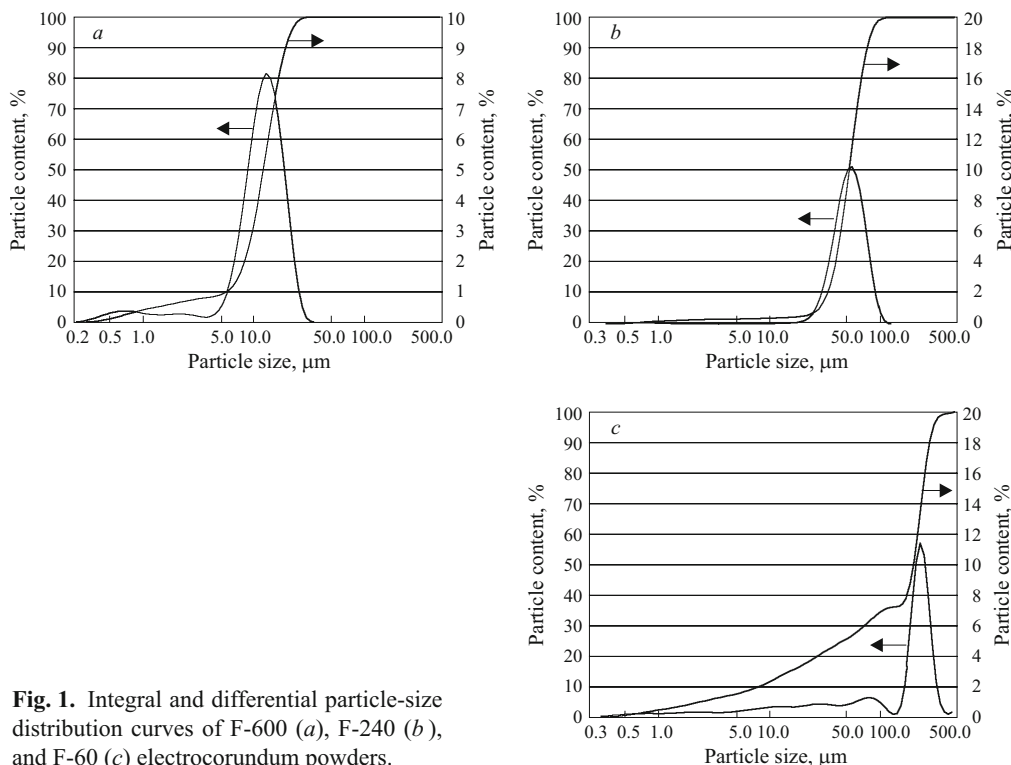
ture, high heat resistance, and high durability. Modern technologies make it possible to obtain porous permeable ceramic materials with prescribed pore size and distribution. Special technological methods make it possible to manufacture large-size and long articles with different configurations [3].

The technology of manufacturing articles from porous permeable ceramic materials is based on the use of ceramic filler-powders with a mono- or narrow-fractional composition together with a binder (high-plasticity clays, liquid glass, bentonite, phosphates). For monofractional powders, the open porosity of the articles is almost independent of the grain size. However, the size of the pores formed in an article is mainly determined by the size of the filler particles as well as by the amount of binder introduced, the degree of compac-

TABLE 1.

Packing type	Coordination number	Computed values of the open porosity (%) according to works cited	
		[5]	[6]
Hexagonal close	12	25.9	25.1
Body-centered cubic	8	31.2	37.3
Simple cubic	6	47.6	47.6
Tetrahedral	4	66.0	65.9
Heesch – Laves	3	87.6	81.5

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**Fig. 1.** Integral and differential particle-size distribution curves of F-600 (*a*), F-240 (*b*), and F-60 (*c*) electrocorundum powders.

tion of the mixes during formation, and the heat-treatment conditions [4].

The open porosity  $42 \pm 3\%$  which has been attained to date for ceramic materials (from monofractional powders) is not high, which foreordains the low efficiency of filtering elements based on them.

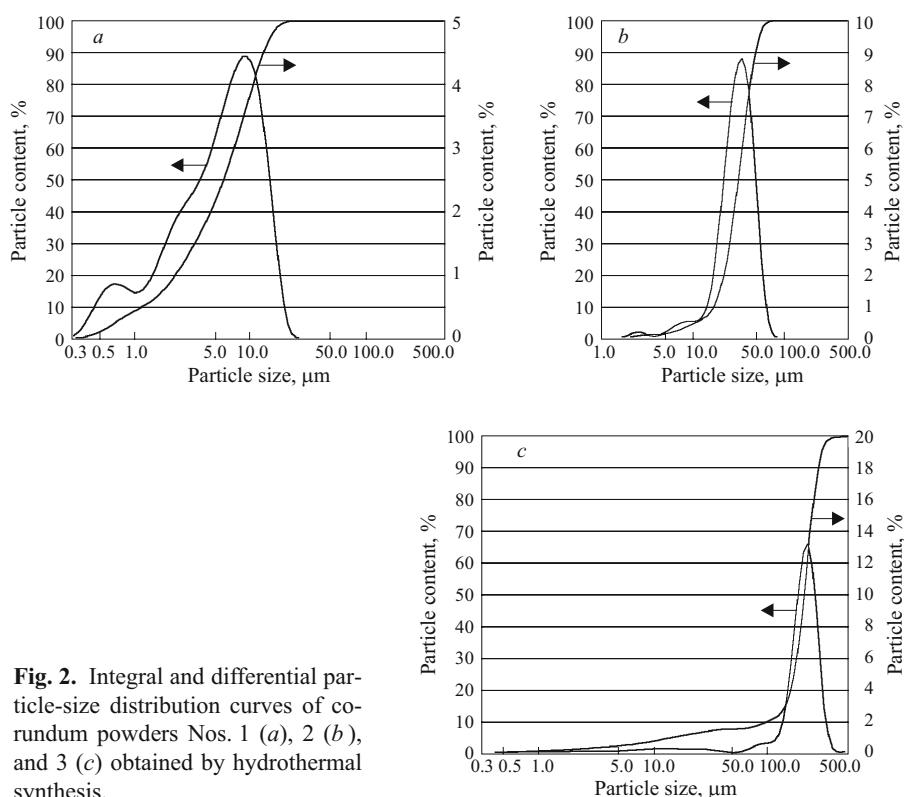
At the same time, calculations performed for different packing of spherical particles show that, in principle, it is possible to obtain ceramic materials with open porosity substantially higher than 40%. The characteristics of the correct packing of spheres (point contact between spheres) are presented in Table 1.

The present work is devoted to solving the question of obtaining in practice permeable ceramic materials with porosity above 40% which are resistant to acids and alkalis.

Two types of filler powders were chosen for the experiments: white electrocorundum powder F-600, F-240, F-60 (GOST 28818-90) and corundum powders obtained by hydrothermal synthesis (Nos. 1–3). The granulometric compositions of these powders are presented in Figs. 1 and 2.

The white electrocorundum powder particles have a fragmental shape charac-

teristic for powders obtained by fragmentation and comminution (Fig. 3*a*). The particles of specially synthesized corundum powder are distorted tetragon-tri-octahedra (Fig. 3*b*).



**Fig. 2.** Integral and differential particle-size distribution curves of corundum powders Nos. 1 (*a*), 2 (*b*), and 3 (*c*) obtained by hydrothermal synthesis.

TABLE 2.

Mix composition	Component content, wt. %	Open porosity, %	Apparent density, g/cm <sup>3</sup>	Compressive strength, MPa
<i>Firing temperature 1400°C</i>				
Corundum powder, hydrothermal synthesis, No. 1	65.0	61.0	1.50	3.5
Sol SiO <sub>2</sub> (2 – 4 nm)	35.0			
Corundum powder, hydrothermal synthesis, No. 1	65.0	53.0	1.80	24.5
Sol SiO <sub>2</sub> (10 – 15 nm)	35.0			
Corundum powder, hydrothermal synthesis, No. 2	76.0	50.0	1.94	12.0
Sol SiO <sub>2</sub> (2 – 4 nm)	24.0			
Corundum powder, hydrothermal synthesis, No. 3	82.0	42.0	2.30	6.2
Sol SiO <sub>2</sub> (2 – 4 nm)	18.0			
Electrocorundum F-600	73.0	47.0	2.10	25.8
Sol SiO <sub>2</sub> (2 – 4 nm)	27.0			
Electrocorundum F-600	68.0	40.6	2.16	84.9
Sol SiO <sub>2</sub> (10 – 15 nm)	32.0			
Electrocorundum F-60	77.0	41.0	2.20	28.8
Sol SiO <sub>2</sub> (10 – 15 nm)	23.0			
<i>Firing temperature 1500°C</i>				
Specially synthesized corundum powder No. 2	62.5	54.2	1.72	16.2
Sol Al <sub>2</sub> O <sub>3</sub> (3 – 6 nm)	37.5			
Specially synthesized corundum powder No. 2	61.0	48.5	1.85	21.7
Sol Al <sub>2</sub> O <sub>3</sub> (9 – 12 nm)	39.0			
Electrocorundum F-600	70.9	43.1	2.17	55.4
Sol Al <sub>2</sub> O <sub>3</sub> (3 – 6 nm)	29.1			
Electrocorundum F-600	68.8	36.2	2.32	95.1
Sol Al <sub>2</sub> O <sub>3</sub> (9 – 12 nm)	21.2			

TABLE 3.

Mix composition	Component content, wt. %	Specific pressing pressure, MPa	Open porosity,* %	Apparent density,* g/cm <sup>3</sup>	Compressive strength,* MPa
Corundum powder, hydrothermal synthesis, No. 1	65.0	10	46.0	2.11	18.5
Sol SiO <sub>2</sub> (2 – 4 nm)	35.0				
Corundum powder, hydrothermal synthesis, No. 1	65.0	10	45.0	2.12	20.1
Sol SiO <sub>2</sub> (10 – 15 nm)	35.0				
Corundum powder, hydrothermal synthesis, No. 3	81.0	20	38.0	2.48	5.8
Sol SiO <sub>2</sub> (2 – 4 nm)	19.0				
Corundum powder, hydrothermal synthesis, No. 3	78.0	20	36.0	2.46	32.8
Sol SiO <sub>2</sub> (10 – 15 nm)	22.0				
Electrocorundum F-600	73.0	10	45.0	1.98	21.6
Sol SiO <sub>2</sub> (2 – 4 nm)	27.0				
Electrocorundum F-600	68.0	10	44.0	1.95	45.0
Sol SiO <sub>2</sub> (10 – 15 nm)	32.0				

\* Firing temperature 1400°C, soaking time 4 h, oxidative medium.

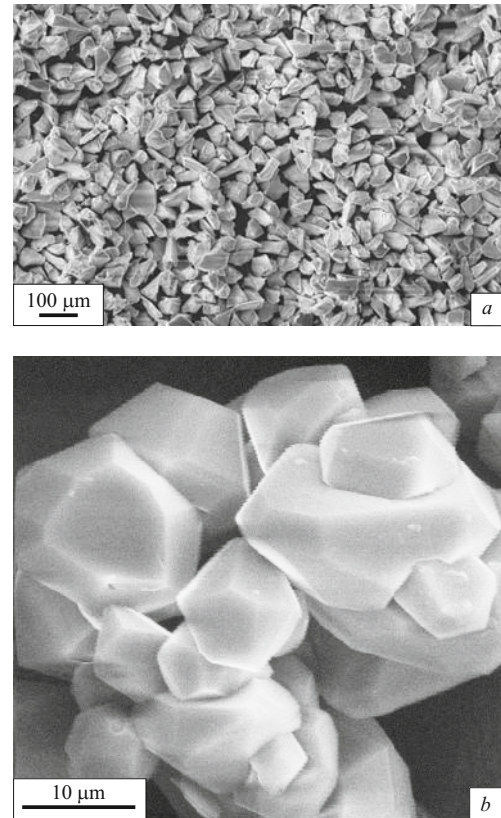
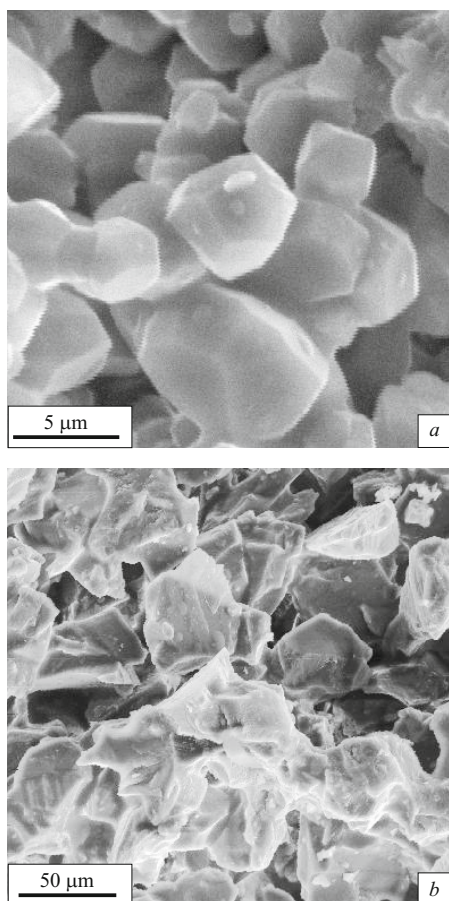


Fig. 3. Shape of crystals of the electrosmelted corundum F-240 (a) and No. 1 corundum obtained by hydrothermal synthesis (b).

The samples of porous permeable ceramic were prepared by two methods — slip casting and semidry pressing. These formation methods were chosen because they are most suitable for implementation in commercial production. A number of assumptions dictated the choice of SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> as the binding sols (their content in the sols by weight of dry matter was 10%). In the first place, because of their size the sol particles, arranging themselves around the particles of the granular filler, should not make a large contribution to the decrease of the open porosity of the system. In the second place, during sintering SiO<sub>2</sub> will interact with Al<sub>2</sub>O<sub>3</sub> and chemically stable mullite will be formed. The results of the investigation of the physical – technical properties of porous permeable ceramic samples obtained by slip casting (firing temperature 1400 and 1500°C, soaking time 4 h, oxidative medium) are presented in Table 2 and the results of semidry pressing are presented in Table 3.

The investigations performed show that monofractional corundum powders can be used to obtain porous permeable ceramic with porosity up to 60% without using spe-



**Fig. 4.** Microstructure of porous permeable ceramic made from No. 1 corundum powder obtained by hydrothermal synthesis (a) and from F-240 electrocorundum powder (b).

cial technological methods, such as consumable additives or additions of foams and foaming-agents. It should be noted that samples with high porosity can be obtained only by slip casting using powders whose crystals have a definite habit. In this case, a nearly tetrahedral packing of the particles in the initial powder in the samples obtains.

Porous permeable materials with high open porosity could find wide industrial applications as adsorbents, catalysts, high-capacity filtering elements, and so on, which work even when they are exposed to acids and alkalis. For this reason, we evaluated the chemical stability of the materials developed.

To perform the experiments evaluating chemical stability, four samples (36 mm in diameter, 5 mm high) with quite close values of the open porosity were chosen. The chemical stability was evaluated by a method adopted in a number of domestic industrial enterprises. Before being tested the samples were dried at 120°C to constant mass. The dried samples were placed in nitric acid (concentration 2.5 mole/liter) or sodium hydroxide (concentration 2.5 mole/liter) and soaked for 60 min at 60°C. Then the samples were washed with distilled water to neutral reaction and dried to constant mass, after which their chemical stability was determined according

**TABLE 4.**

Mix composition	Content of components, wt. %	Open porosity, %	Chemical stability, %	
			NaOH	HNO <sub>3</sub>
Corundum powder, hydrothermal synthesis, No. 1	65.0	53.0	0.51	0.21
Sol SiO <sub>2</sub> (10 – 15 nm)	35.0			
Electrocorundum F-600	73.0	47.0	0.33	0.20
Sol SiO <sub>2</sub> (2 – 4 nm)	27.0			
Specially synthesized corundum powder, No. 2	62.5	54.2	0.18	0.16
Sol Al <sub>2</sub> O <sub>3</sub> (3 – 6 nm)	37.5			
Electrocorundum F-600	70.9	43.1	0.13	0.15
Sol Al <sub>2</sub> O <sub>3</sub> (3 – 6 nm)	29.1			

to the mass lost by the sample. The chemical stability of the porous permeable ceramic with nanodispersed binders consisting of aluminum oxide and silicon oxide sols are presented in Table 4.

The samples prepared with a nanodispersed aluminum oxide binder are chemically more resistant to acid and alkali than the samples made from the same monofractional aluminum oxide powders with nanodispersed silicon oxide binders. The data obtained correlate well with the results obtained in [7]. Of course, the fact that the open porosity is different must be taken into account.

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## REFERENCES

1. B. L. Krasnyi, V. P. Tarasovskii, and A. B. Krasnyi, "Application of ceramic materials for solving ecological problems," *Bezopasn. Okruzh. Sredy*, No. 3, 94 – 96 (2008).
2. B. L. Krasnyi, V. P. Tarasovskii, and A. B. Krasnyi, "Articles made from porous permeable ceramic — new possibilities for technological breakthrough in principal industries," *Novye Ogneupory*, No. 11, 28 – 30 (2008).
3. B. L. Krasnyi and V. P. Tarasovskii, "Filtering elements made from porous permeable ceramic with different microstructure and pores regulatable from macro- to nano- sizes for different industries and the municipal housing economy" in: *Abstracts of Reports at the Conference on Nanotechnologies — Production-2006* [in Russian], Fryazino (2006), pp. 75 – 77.
4. I. Ya. Guzman (ed.), *Chemical Technology of Ceramics* [in Russian], RIF "Stroimaterialy" JSC, Moscow (2003).
5. A. P. Karnaukhov, "Globular model of porous bodies with corpuscular structure," *Kinetika Catalis*, **12**(4), 1025 – 1033 (1971).
6. Yu. N. Kryuchkov, *Modeling of the Porous Structure and Mass Transfer in Powdered Permeable Materials Taking Account of Nonlinear Structural Effects* [in Russian], Kiev (1995).
7. B. L. Krasnyi, V. P. Tarasovskii, E. V. Rakhmanova, and V. V. Bondar, "Chemical stability of ceramic materials in acids and alkalis," *Steklo Keram.*, No. 10, 22 – 24 (2004).